AlGaN Quadruple-band Photodetectors

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***Abstract*- Quadruple back-illuminated ultraviolet metal-semiconductor-metal photodetectors with four different spectral responsivity bands were demonstrated. The average of the full-width at half-maximum (FWHM) of the quantum efficiency peaks was 9.98 nm.**

I. Introduction

$Al_xGa_{1-x}N$ based photodetectors have emerged as an alternative to conventional ultraviolet (UV) sensors with the advent of metal organic chemical vapor deposition (MOCVD) systems [1]-[2]-[3]. Many workers have demonstrated metal-semiconductor-metal (MSM) [4]-[5], Schottky [6], p-i-n [7] and avalanche type [8] AlGaN UV photodetectors successfully. Ultraviolet detectors have a wide range of applications in flame, fire and missile detection, chemical and biological analysis, short distance non-line-of-sight optical communications, as well as emitter calibration. The existing fire warning systems utilize infrared (IR)/IR [9], UV/IR, or UV/visible/IR channels. Multiband narrow-spectrum UV detectors would in turn increase the fire source and range recognition capabilities of such systems and help to eliminate false alarms. One method of narrow spectral-band detection is to employ absorptive epitaxial filter-layers [10]. In the present paper, we report our work on quadruple-band UV MSM photodetectors that are fabricated on a single chip. Metal-semiconductor-metal type photodetectors are preferred since they simplify the growth and fabrication processes, exhibit very low dark currents [11], and allow for operation even in the deep UV [12].

II. Sample Fabrication

The investigated epitaxial sample incorporates nine 500 nm $Al_xGa_{1-x}N$ layers that were grown by MOCVD with decreasing Al concentration in each layer. Optical transmission tests revealed that the Al concentration of the layers varied from 0.50 to 0.08 from bottom to top of the structure. When illuminated from the substrate side, every layer acts as a high-wavelength pass spectral filter for the above layers with a lower Al concentration.

For the fabrication of the quadruple-band photodetectors, the sample surface was lithographically protected and etched during a series of reactive ion etching (RIE) steps. The respective four quadrants of the quadruple photodetector were recess-etched to the first (no etch), third, fifth and seventh layers prior to MSM finger metallization. The spacer layers between the actual photodetector layers were reserved as spectral filters. On the as-grown and three staircase-like etched quadrants of the quadruple photodetector area, MSM photodetectors were fabricated by the deposition of 100 Å Pt / 2000 Å Au finger metallization in a single step. The width and spacing of the interdigitated fingers were 3 µm, and the device active areas were 180 µm × 180 µm. A photomicrograph of the completed quadruple photodetector is shown in Fig. 1. The arrangement of one detector on each quadrant allows for the uniform illumination through a circularly symmetric light probe such as a fiber or a laser beam.

III. Results

The fabricated devices exhibited good dark current characteristics below the level of 10^{-10} A in the 0-100V range. The spectral responsivity of the devices was measured by using a Xe lamp and monochromator assembly. The quantum efficiency of all four devices is plotted in Fig. 2 for the 250 nm - 375 nm spectral range. For an improved visualization of the spectral shape of the response, the quantum efficiency of each detector was normalized to the value at the respective peak wavelength. The exact value of the peak quantum efficiency was 0.25, 0.47, 0.14 and 0.03 for the devices fabricated on quadrants 1, 2, 3 and 4, respectively. Similarly, the full-width-at-half-maximum (FWHM) of the quantum efficiency peak was 8.3 nm, 12.1 nm, 11.4 nm, and 8.1 nm, for the respective devices on quadrants 1, 2, 3 and 4. The wavelength separation at the half-maximum normalized quantum efficiency between the red edge of one peak and the blue edge of the next peak was 15 nm, 18 nm, and 33 nm for the detector pairs 1-2, 2-3, and 3-4, respectively. The separation is a direct result of the existence of the additional absorptive filter layers sandwiched between the detector active layers. The blue edge of each detector response coincides with the cut-off wavelength of the filter layer beneath.

IV. Conclusions

In conclusion, we designed, fabricated, and tested monolithic quadruple band UV MSM photodetectors on a multilayer AlGaN heterostructure. The sample structure consisted of nine discrete layers: four active device layers sandwiched between five spectral filter layers. The average of the FWHM of the quantum efficiency peaks was 9.98 nm. This result demonstrates that it is possible to obtain the desired spectral position, FWHM, and peak-to-peak separation by the incorporation of filter layers and the optimization of the layer compositions and thicknesses in the epitaxial structure.

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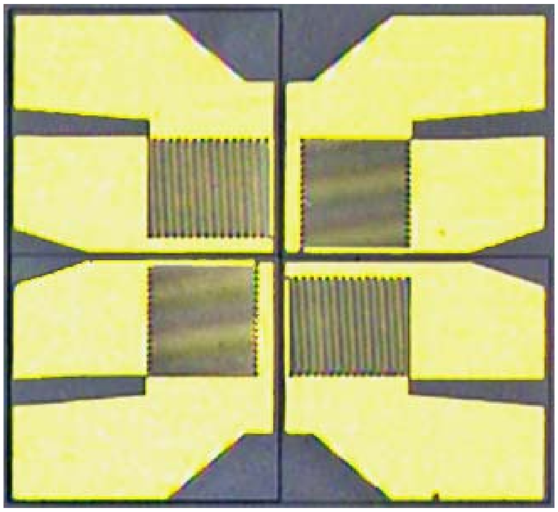

Fig. 1 Photomicrograph showing quadruple-band MSM photodetectors.

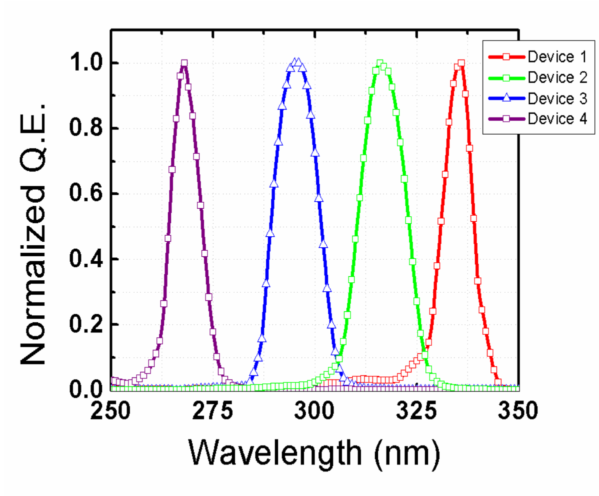

Fig. 2 Normalized quantum efficiency of quadruple-band photodetectors.

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